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(54) Title: METHOD FOR CONTROLLING AN ELECTROSTATIC PRECIPITATOR

(57) Abstract

A method for controlling an electrostatic precipitator unit, which comprises discharge electrodes and collecting electrodes. Between the electrodes a varying high voltage is maintained by a pulsating direct current supplied thereto. Dust deposited on the collecting electrodes is removed by mechanical rapping during recurrent, relatively short rapping periods separated by rapping intervals of essentially longer duration. During the rapping period, the voltage between the electrodes is reduced in relation to the voltage between the electrodes during the intervals between the rapping periods. The frequency, pulse charge and/or pulse duration of the pulsating direct current are varied, thereby obtaining a plurality of combinations of frequency, charge and duration. A combination of frequency, charge and duration which is optimal to the operation of the precipitator unit is determined. One or more of the parameters rapping frequency, rapping force, number of raps per rapping period, and current or voltage during the rapping period are adjusted in dependence on the pulse frequency of the established optimal combination of frequency, charge and duration.

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Method for Controlling an Electrostatic Precipitator

FIELD OF THE INVENTION

The present invention relates to a method for controlling an electrostatic precipitator unit, which comprises discharge electrodes and collecting electrodes. Between the electrodes, a varying high voltage is maintained by a pulsating direct current supplied to the electrodes. Under the action of the electric field between the electrodes, the particles charged by the current between the electrodes are moved towards the collecting electrodes and deposited thereon. Dust deposited on the collecting electrodes is removed by mechanical rapping during recurrent, relatively short rapping periods separated by rapping intervals of essentially longer duration. During the rapping period, the voltage between the electrodes is reduced in relation to the voltage between the electrodes during the intervals between the rapping periods.

BACKGROUND OF THE INVENTION

Electrostatic precipitators are suitable in many contexts, especially in flue gas cleaning. Their design is robust and they are highly reliable. Moreover, they are most efficient. Degrees of separation above 99.9% are not unusual. Since, when compared with fabric filters, their operating costs are low and the risk of damage and stoppage owing to functional disorders is considerably smaller, they are a natural choice in many cases.

In order to optimise the operation and reduce the energy consumption at the same time as the separation is improved, several methods for pulse feeding of the current to the electrostatic precipitator unit have been suggested. Examples are to be found in US 4,052,177 and US 4,410,849. The former suggests the feeding of pulses in the order of

microseconds, which means high demands on the electric equipment. The latter suggests pulses in the order of milliseconds, which may be achieved simply by selectively controlling thyristors, to which mains frequency alternating current is supplied.

A procedure that is central to the function of an electrostatic precipitator is the rapping of the collecting electrodes. By rapping, the separated dust is released from the electrodes and falls down in collecting hoppers intended therefor. The rapping frequency, i.e. how often the rapping is effected per unit of time, is controlled mainly by two opposite requirements. Since the dust cake on the collecting electrode by its growth gradually deteriorates the function of the filter, rapping is desirable before the dust cake becomes too thick. On the other hand, in each rapping, a considerable amount of dust is released and reentrained to the flue gas, resulting in a momentarily reduced degree of separation. Besides, a too high rapping frequency results in the formation of a hard coating that adheres to the collecting electrode and is very difficult to remove by rapping. The selected rapping frequency will be a compromise which should, for instance, maximise the average degree of separation. Other rapping parameters that may be varied are the number of raps during each rapping period and the force thereof. Also the electric voltage and/or current between discharge electrode and collecting electrode may be reduced, disconnected or even reversed during rapping in order to facilitate the release of the dust during rapping. Reversal is disclosed in for example SE 455 048.

An electrostatic precipitator consists of a number of precipitator units which are connected in series. Since the amount of dust separated, in a given unit, per unit of time decreases strongly with the increasing number of precipitator units passed by the flue gas, the rapping must be controlled separately for each precipitator unit. To make it possible to separate dust released in a precipitator

unit during rapping once more in a succeeding precipitator unit, the rapping should, however, be coordinated so as not to be carried out at the same time in several precipitator units. Also the rapping sequence in a precipitator unit containing a plurality of collecting electrodes to be rapped is selected carefully, such that all electrodes are rapped once during a so-called rapping cycle, where the rapping sequence for the individual electrodes in one precipitator unit has been selected for the purpose of minimising the reentrainment of dust to the flue gas.

The growing number of control parameters in an electrostatic precipitator has increased the complexity in the control systems. One drawback with this is that the actual adjustment of rapping parameters such as the rapping frequency increases the disturbance in the function of the precipitator.

If adjustment of e.g. rapping frequency is effected manually by means of the reading of an opacimeter (tester for the optical density of smoke), this takes such a long time that an unfavourable value of the rapping frequency during the adjustment can result in increased emissions during the time of adjustment. Furthermore, there is a risk that operational variations affect the adjustment negatively if considerable changes in the concentration of dust, the composition of dust or the gas temperature occur during the time needed for the adjustment. This already applies to the adjustment of the electric parameters of the precipitator and is a still more difficult problem in the adjustment of, for instance, the rapping frequency, since the rapping frequency varies between minutes for the first precipitator unit to several hours or even days for the last one.

US 4,432,062 discloses an automatic optimisation of the rapping frequency in terms of the average value of the remaining dust content in the flue gas after the filter. The drawbacks of this method are a dependence on the measuring of the remaining dust content in the flue gas and the

fact that the rapping frequency varies over several orders of magnitude between the precipitator units. When selecting the rapping frequencies of the precipitator units as independent parameters, this leads to simultaneous optimisation of many parameters, which easily results in sub-optimisation or the absence of convergence of the optimising algorithm. If predetermined functional relations between the rapping frequencies are selected, e.g. constant relative proportions, on the other hand the number of degrees of freedom is restricted too much, involving a risk of sub-optimisation. The corresponding conditions apply to other rapping parameters, such as the voltage/current during rapping.

OBJECT OF THE INVENTION

It has been found that the methods tested up to now, for controlling the rapping parameters do not always result in the optimal combination of parameters and, above all, are far too slow.

The object of the invention is to control the parameters for rapping of collecting electrodes in an electrostatic precipitator, thereby achieving considerable advantages in the form of lower emissions by a changed evaluation of the operating conditions. This is the case especially in comparison with the methods that are based on measurement of dust concentration.

A main object of the present invention is to suggest a method for controlling the current or voltage during a rapping period.

A second object of the present invention is to suggest a method for individual controlling of one or more parameters for rapping such as rapping force, rapping frequency, number of raps per rapping period, which can, more easily than in prior art, follow variations in operation by quickly adjusting the rapping parameters.

SUMMARY OF THE INVENTION

The present invention relates to a method for controlling an electrostatic precipitator unit, which comprises discharge electrodes and collecting electrodes. Between the electrodes there is maintained a varying high voltage by a pulsating direct current supplied thereto. Under the action of the electric field between the electrodes, the particles charged by the current between the electrodes are moved towards the collecting electrodes and deposited thereon. Dust deposited on the collecting electrodes is removed by mechanical rapping during recurrent, relatively short, rapping periods separated by rapping intervals of essentially longer duration. During each rapping period, all collecting electrodes of the unit are cleaned by one or more mechanical impulses, individually or in groups, being supplied to the collecting electrodes in a predetermined manner. During the rapping period, the voltage between the electrodes is reduced in relation to the voltage between the electrodes during the intervals between the rapping periods.

In the method according to the invention, the frequency, pulse charge and/or pulse duration of the pulsating direct current are varied, thereby obtaining a plurality of combinations of frequency, charge and duration. A combination of frequency, charge and duration is established, which is optimal to the operation of the precipitator unit. One or more of the parameters rapping frequency, rapping force, number of raps per rapping period and current or voltage during the rapping period are controlled in dependence on the pulse frequency for the established optimal combination of frequency, charge and duration. The current or voltage during the rapping period is adjusted in dependence on the pulse frequency for the determined optimal combination of frequency, charge and duration.

GENERAL DESCRIPTION OF THE INVENTION

The basic idea of the invention is, that under given circumstances, which are constant as far as possible, a purely electric optimisation is effected such that optimal values of pulse frequency, pulse charge and pulse duration are obtained. The pulse frequency obtained at the determined optimal combination is then used as a controlling parameter for selection of the parameters such as voltage or current during the rapping period.

One way to use the invention is that the voltage and/or current during the rapping period are reduced if the pulse frequency at the determined optimal combination of frequency, charge and duration is below a first predetermined limit. This reduction is preferably done essentially proportionally to the pulse frequency, or by a factor essentially linearly dependent on the frequency if the pulse frequency at the determined optimal combination of frequency, charge and duration is below the first predetermined limit.

Another way to use the invention is that the voltage or current is reduced by an essentially constant factor or is selected essentially constant at a low value if the pulse frequency at the determined optimal combination of frequency, charge and duration is below a second predetermined limit.

A preferred mode of operation is that the voltage or current is kept unchanged during the rapping period if the pulse frequency at the determined optimal combination of frequency, charge and duration is above a first predetermined limit, that it is reduced by an essentially constant factor, or is selected essentially constant at a low value if the pulse frequency at the determined optimal combination of frequency, charge and duration is below a second predetermined limit, and that the voltage is lowered and/or that the current is reduced essentially proportionally to

the pulse frequency, or by a factor essentially linearly dependent on the frequency, if the pulse frequency at the determined optimal combination is below the first predetermined limit, but above the second predetermined limit.

The first predetermined limit may be selected in the range 10-100 Hz, preferably in the range 15-40 Hz. The second predetermined limit may be selected in the range 1-30 Hz, preferably in the range 4-10 Hz.

The rapping parameters can, in addition to the optimal pulse frequency, also be a function of the minimum level of the varying high voltage immediately before the rapping period and/or of the average value of the pulsating direct current immediately before the rapping period. This is preferably done in such a way that a higher value of the minimum level of the varying voltage immediately before the rapping period yields a higher value of the voltage and/or current during the rapping period, and that a higher average value of the pulsating direct current immediately before the rapping period yields a higher value of the voltage and/or current during the rapping period.

Within the inventive idea one may also adjust the rapping frequency, rapping force or the number of raps per rapping period in dependence on the pulse frequency of the determined optimal combination of frequency, charge and duration. Preferably this is done such that the number of consecutive raps on an individual collecting electrode or group of collecting electrodes during a rapping period is selected higher at a lower pulse frequency.

Further one may adjust the number of consecutive raps on an individual collecting electrode or group of collecting electrodes during a rapping period also in dependence on the minimum level of the varying high voltage immediately before the rapping period or in dependence on the average value of the pulsating direct current immediately before the rapping period.

The rapping frequency may advantageously be selected higher at a higher value of the pulse frequency for the

determined optimal combination of frequency, charge and duration.

Another mode of operation includes variation of the voltage and/or current during the rapping period also in dependence on the point of time of the individual raps on the collecting electrodes. This is preferably done in such a way that the voltage and/or current during the rapping period are adjusted intermittently between two values essentially synchronously with the raps on the collecting electrodes.

The optimisation of the pulse parameters and selection of the rapping parameters are carried out individually for each precipitator unit with its associated high voltage supply and rapping equipment, which means that the various time scales of the rapping in the different precipitator units need not be mixed in the optimising process.

The method is particularly convenient when the pulsating direct current has the form of a pulse train, which is synchronised with the frequency of the mains voltage and in which the pulses are generated by a part of a half-wave of the mains voltage being supplied, by means of a phase angle controlled rectifier (thyristor) after step-up transformation, to the electrodes of the precipitator, whereupon a plurality of periods of the mains voltage are allowed to pass without current being supplied to the electrodes. Then a part of a half-wave is again supplied, followed by a plurality of periods without current etc.

In this manner, the frequency, pulse charge and/or pulse duration of the pulsating direct current can be varied such that a plurality of combinations of frequency, charge and duration are obtained. For each combination, a figure of merit is measured or calculated. The figures of merit are used to determine an optimal combination. The parameters such as voltage or current during the rapping period are controlled as a function of the pulse frequency for the determined optimal combination.

Examples of figures of merit can be maximum peak value, maximum average value or maximum valley value of the voltage between the electrodes of the precipitator. Such a method is suggested in US 4,311,491.

It may advantageously also be a value determined on more sophisticated grounds, such as the ratio between peak voltage and pulse charge, possibly when one of these parameters is kept constant during the adjustment. This is suggested in EP 0 184 922.

A convenient and effective method for determining a figure of merit, where each combination of parameters can be reflected by an individual figure of merit is, as suggested in PCT/SE92/00815, the determining of a reference voltage level, between the peak value and the valley value of the voltage between discharge electrodes and collecting electrodes, and ascribing a positive value to the time during which the voltage is above this level, and ascribing a negative value to the time during which the voltage is below this level, by weighting according to the function

$$A = U\cdot(U-U_{ref})$$

wherein U is the voltage for a given point of time between the electrodes in the precipitator.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail with reference to the accompanying drawings in which:

Fig. 1 shows the fundamental relation between current and voltage, as a function of the time, in an electrostatic precipitator;

Fig. 2 shows an actually measured voltage, as a function of the time, in an electrostatic precipitator;

Fig. 3 shows the peak value and the minimum value of the voltage between the electrodes in an electrostatic precipitator at a constant pulse frequency, as a function of the average value of the current through the precipitator;

Fig. 4 shows the fundamental relation between the average value of the current through a precipitator and the associated peak value, average value and minimum value of the voltage between the electrodes of the precipitator under operating conditions where electric discharges in a separated dust layer may occur;

Fig. 5 illustrates a method of evaluating the voltage between the electrodes of a precipitator;

Fig. 6 is a simplified view of a plant for carrying out the proposed method for controlling the current and/or voltage reduction of an electrostatic precipitator;

Fig. 7 is a schematic view showing the relation between the optimal pulse frequency and the current through the precipitator during rapping; and

Fig. 8 is a view of a partially linear approximation of the function according to Fig. 7, suited for a controlling algorithm.

DESCRIPTION OF EMBODIMENTS

Fig. 1a shows the general relation between current and voltage in an electrostatic precipitator supplied with current from a phase angle controlled rectifier consisting of thyristors, when the thyristors are fired in all the half periods of the alternating voltage. Fig. 1b shows the same relation when the thyristors are fired merely in every third half period. The method according to the present invention will ordinarily be used at essentially lower firing

frequencies than the showed ones, which for the sake of clarity have not been drawn to scale. The relation between the levels therefore is also completely irrelevant.

Fig. 2 shows the actually measured voltage in a more realistic situation, where the thyristors are fired in every ninth half period and then yield a very steep voltage increase, whereupon the voltage first falls steeply and then more and more slowly. The great difference between the peak value and the minimum value of the voltage between the electrodes is fully realistic. The scale change makes comparisons with the preceding Figure unsuitable. In Fig. 2, the peak value of the voltage is about 58 kV and the minimum value of the voltage about 16 kV. Current pulses are supplied with a frequency of about 11 Hz.

If the firing angles of the thyristors are varied at a constant frequency, both peak and minimum values of the voltage will vary. Under favourable operating conditions or close to optimal operation, the minimum value is relatively independent of the firing angle, while the peak value grows monotonously with a decreasing firing angle, i.e. an increased conducting period of the thyristors. Under difficult operating conditions and when operating with unsuitable parameters, the minimum voltage decreases, even at low current, with a decreasing firing angle, and at higher currents both the average value and the peak value of the voltage decrease. Fig. 3 illustrates the actually measured relations for a given pulse frequency in close to optimal operation.

Fig. 4 illustrates the fundamental relations between current and voltage in a precipitator when separating a dust having high resistivity. The curves 41, 42 and 43 correspond to the minimum value 41, average value 42 and peak value 43 of the voltage between the electrodes of the precipitator. All three curves have a local maximum. This can be seen as an example of electric parameters indicating optimal operation. By varying the firing angle and pulse frequency, it is possible to find an optimal combination.

Fig. 5 illustrates a further method for determining the figure of merit for a given combination of parameters. Fig. 5 is a picture, which for the sake of clarity is somewhat distorted, showing how the voltage between the electrodes of the precipitator varies with time during the interval from the start of a current pulse to the start of the next current pulse. It is also indicated that the measuring of the voltage between the electrodes of the precipitator takes place at a plurality of discrete and equidistant points of time. In practice, the measuring takes place at essentially more points of time than those shown, for instance 1-3 times per millisecond. These measured values are stored in a preferably computerised control unit 630, shown in Fig. 6, and by means of the value of U_{ref}, which is also stored in the control unit 630, $A_i = U_i \cdot (U_i - U_{ref})$ is calculated for each measuring point. The average value of A_i is calculated automatically in the control unit 630, and the result is stored as a figure of merit for the relevant combination of pulse frequency and firing angle of the thyristors in the corresponding rectifier 621, 622 and 623.

Fig. 6 shows schematically a plant for carrying out the present method. A precipitator 600 having an inlet duct 641 and an outlet duct 642 comprises three precipitator units 601, 602, 603 each having a dust hopper 611, 612, 613. The precipitator units are supplied with pulsating direct current from three rectifiers 621, 622, 623. The rectifiers 621-623 are controlled and monitored by a control unit 630. The control unit 630 also communicates with devices 651, 652 and 653 for rapping of the collecting electrodes in the precipitator units 601, 602 and 603.

Fig. 7 illustrates an assumed fundamental relation between pulse frequency and optimal current reduction, during the rapping period, shown as the current during rapping period in percent of the current in the rapping interval. The basic experience is that no reduction shall be done at high frequencies for the current pulses and

reduction to a low value, perhaps even to zero, for low frequencies.

Fig. 8 shows an approximation of the function in Fig. 7 as a partially linear function, suited for a controlling algorithm. If the optimal combination of pulse parameters means a pulse frequency lower than L_2 = 8 Hz, the current is reduced to 10% of the previous value. If the optimal combination of pulse parameters means a pulse frequency higher than L_1 = 30 Hz, no reduction at all takes place. If the pulse frequency is between L_2 = 8 Hz and L_1 = 30 Hz a linear relation between pulse frequency and current reduction is presumed such that a higher pulse frequency yields a higher current ratio. A suitable changing tactic must be based on certain experience of the plant involved and possibly also of the dust in the gas to be cleaned.

In the suggested method, the rectifier 621 supplies, with parameters varying according to a predetermined principle, pulsating direct current to the electrodes (not shown) of the unit 601. The control unit 630 evaluates the supplied pulse-shaped current and the occurring voltage and calculates a figure of merit for each combination of parameters or for each group of combinations. According to a predetermined strategy, the combination of parameters which may be considered the electrically optimal one is selected by means of these figures of merit, and the operation continues with this established combination of parameters, as an example at a pulse frequency of 18 Hz. During rapping, the current which serves as an example of a rapping parameter is decreased. Following the algorithm presented in Fig. 8, the current is then, during the rapping period, reduced to 50% of the average value immediately before.

At short intervals, an electric optimisation of the current supply to all three units 601, 602, 603 takes place. This is initiated and evaluated by the control unit 630.

For the units 602 and 603 positioned downstream, the selection of optimal rapping parameters during rapping is carried out in the same manner.

A change of one or more rapping parameters takes place automatically, when needed, before each rapping period. This can also be carried out after alarm from optionally monitoring sensing means (not shown) for the amount of dust or other measured values characterising the gas in the outlet 642 of the precipitator.

ALTERNATIVE EMBODIMENTS

The method according to the invention is of course not limited to the embodiment described above, but may be modified in a number of ways within the scope of the appended claims.

The method can be applied to a plurality of other techniques of supplying current in the form of pulses to electrostatic precipitators. Examples of such techniques are pulse-width-modulated high frequency and other forms of so-called "switched mode power" as well as the use of thyristors, which can be "switched off". The method is also suited for use in the very special pulse rectifiers which generate pulses in the order of microseconds.

CLAIMS

1. A method for controlling an electrostatic precipitator unit,

comprising discharge electrodes and collecting electrodes, between which a varying high voltage is maintained, by a pulsating direct current supplied to the electrodes, such that under the action of the electric field between the electrodes, the particles charged by the current therebetween are moved towards the collecting electrodes and are deposited thereon,

dust deposited on the collecting electrodes being removed by mechanical rapping of the collecting electrodes by one or more impulses being periodically supplied to the electrodes individually or in groups in a predetermined manner, such that all the collecting electrodes of the unit are cleaned during recurrent, relatively short rapping periods separated by rapping intervals of considerably longer duration,

and the voltage between the electrodes of the precipitator unit and/or the current supplied to the electrodes during the rapping period being reduced in relation to the voltage and the current, respectively, during the intervals between the rapping periods,

c h a r a c t e r i s e d in

that the frequency, pulse charge and/or pulse duration of the pulsating direct current are varied, thereby obtaining a plurality of combinations of frequency, charge and duration,

that a combination of frequency, charge and duration which is optimal to the operation of the precipitator unit is determined, and

that one or more of the parameters rapping frequency, rapping force, number of raps per rapping period, and current or voltage during the rapping period are adjusted,

current or voltage during the rapping period being adjusted in dependence on the pulse frequency for the determined optimal combination of frequency, charge and duration.

2. The method as claimed in claim 1, c h a r a c t e r i s e d in that the voltage and/or current during the rapping period are reduced if the pulse frequency at the determined optimal combination of frequency, charge and duration is below a first predetermined limit.

3. The method as claimed in claim 2, c h a r a c t e r i s e d in that the voltage and/or current, during the rapping period, are reduced essentially proportionally to the pulse frequency, or by a factor essentially linearly dependent on the frequency if the pulse frequency at the determined optimal combination of frequency, charge and duration is below the first predetermined limit.

4. The method as claimed in claim 2, c h a r a c t e r i s e d in that the voltage and/or current are reduced by an essentially constant factor or is selected essentially constant at a lowest value if the pulse frequency at the determined optimal combination of frequency, charge and duration is below a second predetermined limit.

5. The method as claimed in any one of claims 1-4, c h a r a c t e r i s e d in that the voltage and/or current are kept unchanged during the rapping period if the pulse frequency at the determined optimal combination of frequen-

cy, charge and duration is above a first predetermined limit,

that the voltage and/or the current are reduced during the rapping period by an essentially constant factor, or is selected essentially constant at a lowest value if the pulse frequency at the determined optimal combination of frequency, charge and duration is below a second predetermined limit, and

that the voltage is lowered and/or that the current is reduced during the rapping period essentially proportionally to the pulse frequency, or by a factor essentially linearly dependent on the frequency, if pulse frequency at the determined optimal combination is below the first predetermined limit, but above the second predetermined limit.

6. The method as claimed in any one of claims 2-5, c h a r a c t e r i s e d in that the first predetermined limit is selected in the range 10-100 Hz, preferably in the range 15-40 Hz.

7. The method as claimed in any one of claims 4-6, c h a r a c t e r i s e d in that the second predetermined limit is selected in the range 1-30 Hz, preferably in the range 4-10 Hz.

8. The method as claimed in any one of claims 1-7, c h a r a c t e r i s e d in that the voltage and/or current during the rapping period are adjusted also in dependence on the minimum level of the varying high voltage immediately before the rapping period.

9. The method as claimed in any one of claims 1-8, c h a r a c t e r i s e d in that the voltage and/or the current during the rapping period are adjusted also in

dependence on the average value of the pulsating direct current immediately before the rapping period.

10. The method as claimed in claim 8, c h a r a c t e r i s e d in that a higher value of the minimum level of the varying voltage immediately before the rapping period yields a higher value of the voltage and/or current during the rapping period.

11. The method as claimed in claim 9, c h a r a c t e r i s e d in that a higher average value of the pulsating direct current immediately before the rapping period yields a higher value of the voltage and/or current during the rapping period.

12. The method as claimed in any one of the preceding claims, c h a r a c t e r i s e d in that the rapping frequency, rapping force or the number of raps per rapping period are adjusted in dependence on the pulse frequency of the determined optimal combination of frequency, charge and duration.

13. The method as claimed in claim 12, c h a r a c t e r i s e d in that the number of consecutive raps on an individual collecting electrode or group of collecting electrodes during a rapping period is selected higher at a lower pulse frequency of the determined optimal combination of frequency, charge and duration.

14. The method as claimed in claim 12 or 13, c h a r a c t e r i s e d in that the number of consecutive raps on an individual collecting electrode or group of collecting electrodes during a rapping period is adjusted also in dependence on the minimum level of the varying high voltage immediately before the rapping period.

15. The method as claimed in claim 12 or 13, characterised in that the number of consecutive raps on an individual collecting electrode or group of collecting electrodes during a rapping period is adjusted also in dependence on the average value of the pulsating direct current immediately before the rapping period.

16. The method as claimed in claim 12, characterised in that the rapping frequency is selected higher at a higher value of the pulse frequency for the determined optimal combination of frequency, charge and duration.

17. The method as claimed in any one of the preceding claims, characterised in that the voltage and/or current during the rapping period are adjusted also in dependence on the point of time of the individual raps on the collecting electrodes.

18. The method as claimed in claim 17, characterised in that the voltage and/or current during the rapping period are adjusted intermittently between two values essentially synchronously with the raps on the collecting electrodes.

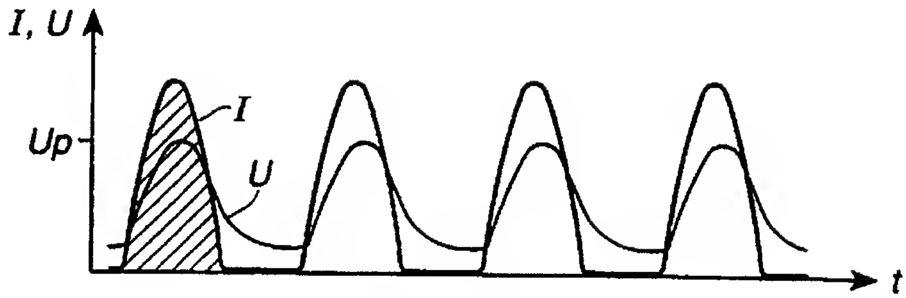

Fig. 1a

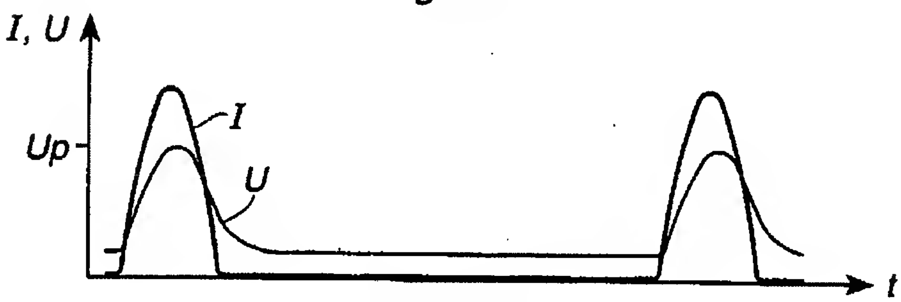

Fig. 1b

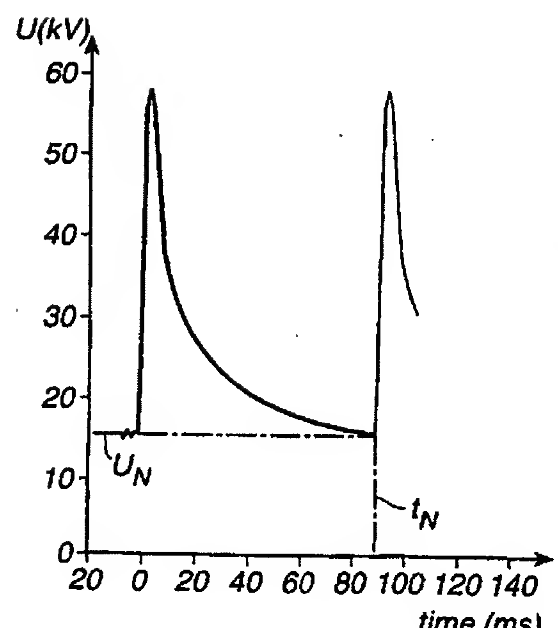

Fig. 2

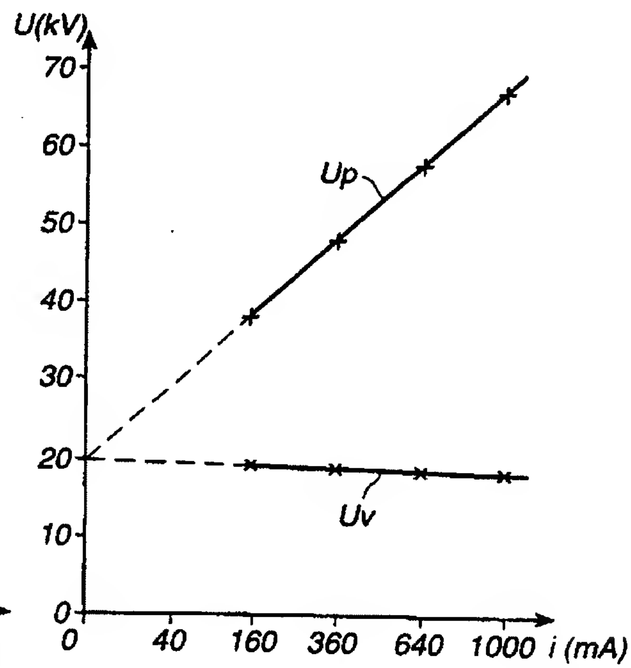

Fig. 3

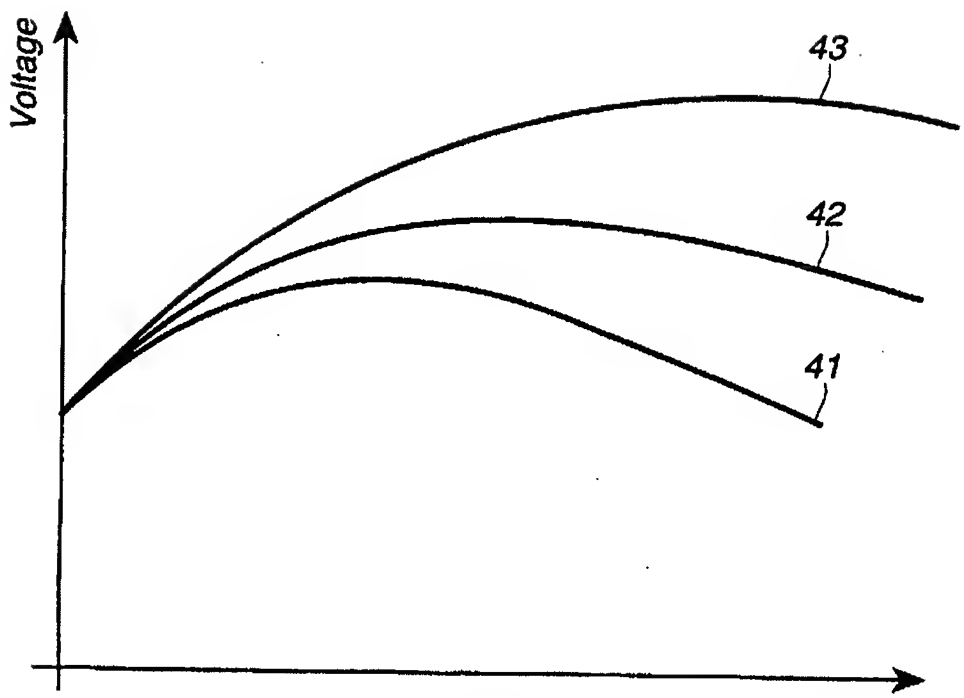

Fig. 4

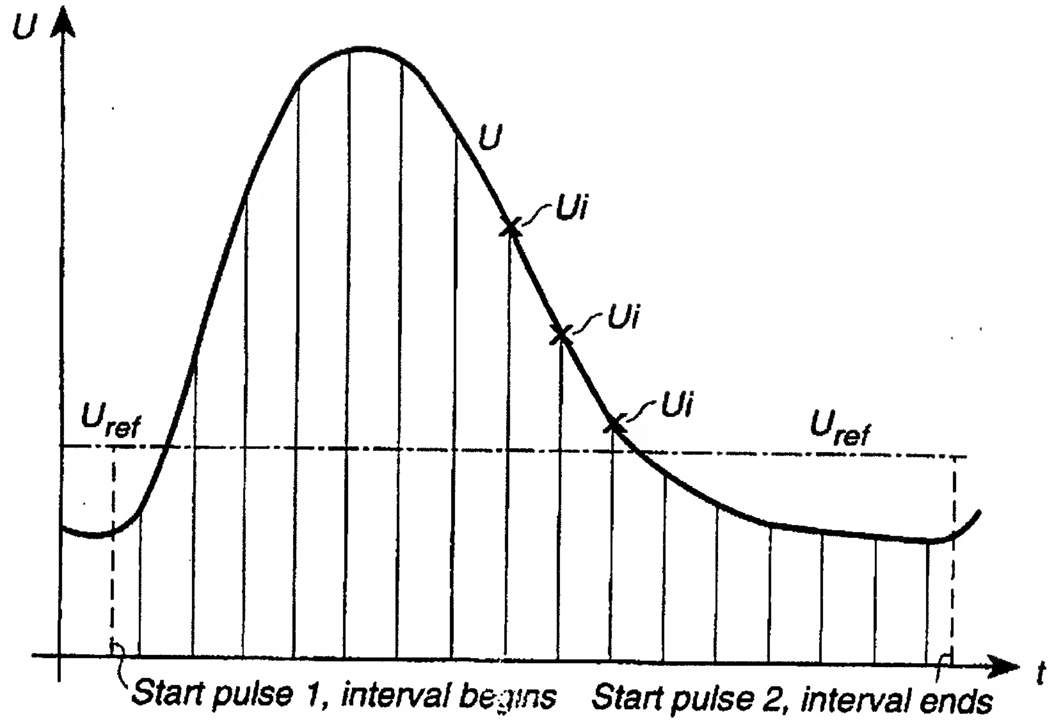
U
U
Ui
Ui
Ui
U_{ref}
U_{ref}
t
Start pulse 1, interval begins
Start pulse 2, interval ends

Fig. 5

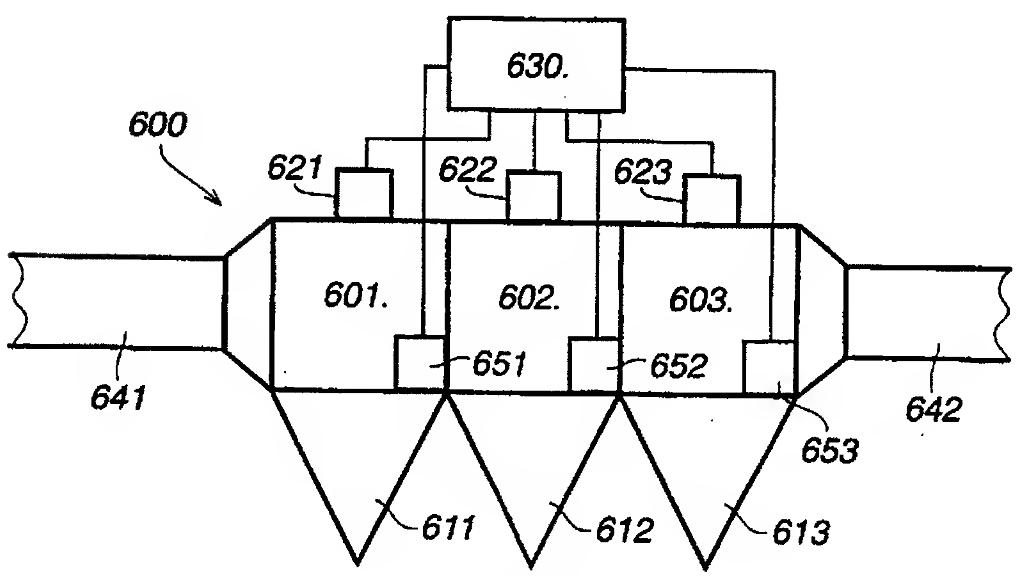
630.
600
621
622
623
601.
602.
603.
651
652
641
642
653
611
612
613

Fig. 6

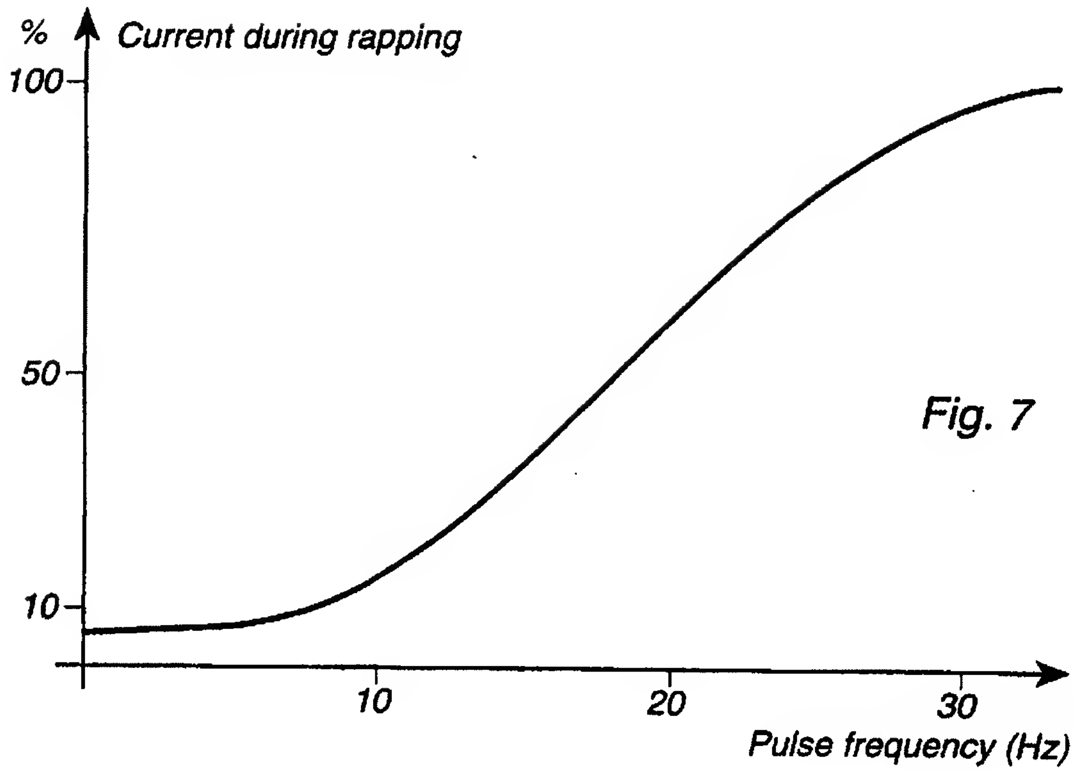
%
Current during rapping
100
50
10
10
20
30
Pulse frequency (Hz)

Fig. 7

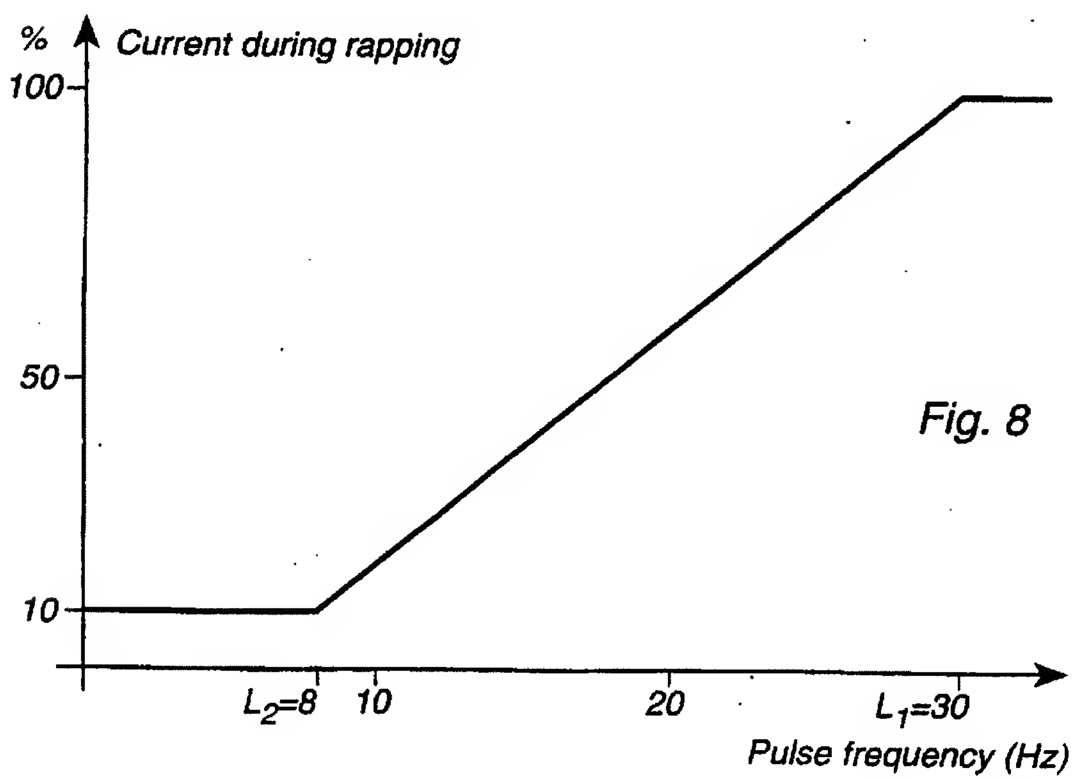
%
Current during rapping
100
50
10
L2=8
10
20
L1=30
Pulse frequency (Hz)

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00494

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B03C 3/68, B03C 3/74

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B03C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9310902 A1 (ABB FLÄKT AB), 10 June 1993 (10.06.93), abstract --	1
A	EP 0039817 A1 (METALLGESELLSCHAFT AG ET AL), 18 November 1981 (18.11.81), page 8, line 5 - line 17, abstract --	1
A	Patent Abstracts of Japan, Vol 7,No 175, C-179, abstract of JP,A,58-81452 (HITACHI PLANT KENSETSUK.K.), 16 May 1983 (16.05.83) -- --------	1

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
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- "B" erlier document but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "&" document member of the same patent family

Date of the actual completion of the international search 2 July 1997	Date of mailing of the international search report 15 -07- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Ulf Nyström Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/06/97

International application No.
PCT/SE 97/00494

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